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PESTS NOT KNOWN TO OCCUR IN THE UNITED STATES OR OF LIMITED DISTRIBUTION NO. 78: SUGARCANE DOWNY MILDEW

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Disease

Sugarcane downy mildew

Pathogen

Peronosclerospora sacchari (T. Miyake) Shirai & K. Hara

Selected Synonyms

Sclerospora sacchari T. Miyake

Class: Order: Family

Oomycetes: Peronosporales: Peronosporaceae

Economic Importance

Sugarcane downy mildew can be severe on sugarcane and corn. Serious problems occurred in Queensland, Australia, in the 1940's (Leece 1941). In Taiwan, two epiphytotics peaked in 1954 and 1964 after releases of susceptible cultivars of sugarcane and corn. The peak in 1964 occurred only 4 years after release of a very susceptible corn cultivar, causing yield losses of 31-42 percent (Chang 1970). Programs in both countries reduced the disease so that it has not been observed since 1958 in Australia (Commonwealth Mycological Institute 1976, Morschel 1980), and levels are insignificant in Taiwan (Sun et al. 1976).

Hosts

Naturally infected hosts include *Miscanthus* (*Eulalia*) (Kenneth 1981), *Saccharum officinarum* (sugarcane), *Sorghum bicolor* (grain sorghum) (Leece 1941), *Tripsacum* (Kenneth 1981), and *Zea mays* (corn, teosinte) (Leece 1941, Sun et al. 1976).

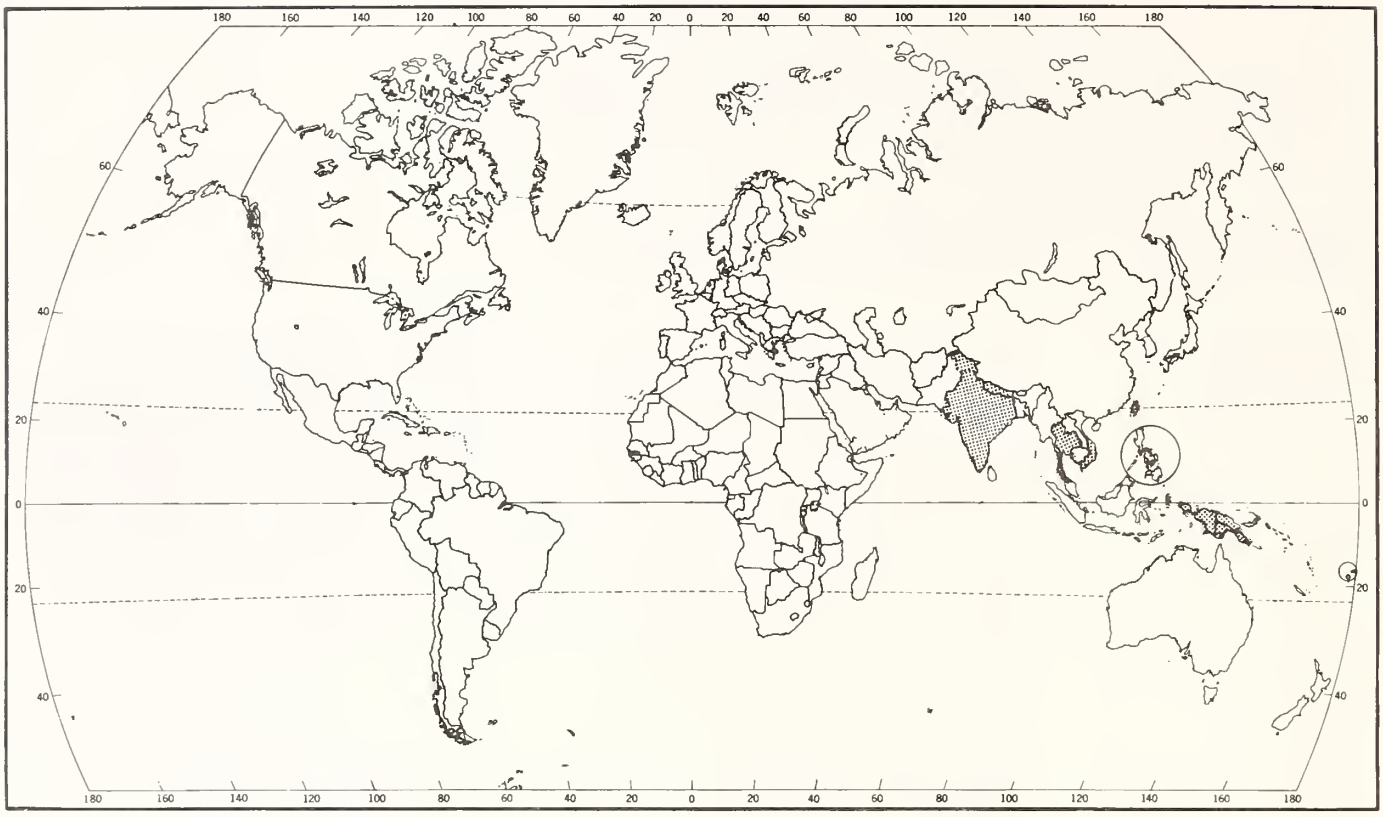
This pathogen is freely transmitted between corn and sugarcane, but corn is more susceptible (Leece 1941, Sun 1970). Sorghum was naturally infected in Queensland but involved only a few plants that sporulated lightly (Leece 1941).

Inoculation studies indicate that American corn cultivars and breeding lines are highly susceptible (Bonde 1980). Potential hosts in the United States include species from the grass tribes Andropogoneae (*Andropogon*, *Bothriochloa*, *Eulalia*, *Saccharum*, *Schizachyrium*, and *Sorghum*) and Maydeae (*Tripsacum* and *Zea*) (Bonde and Peterson 1983).

General Distribution

Sugarcane downy mildew appears to be confined to tropical and subtropical regions (Sun 1970). The Commonwealth Mycological Institute (1976, 1980) listed the following countries unless cited by other authors: China (only Taiwan), Fiji, India, Indonesia (W. Irian), Japan, Nepal (Frederiksen and Renfro

1977), Papua New Guinea, Philippines, South Vietnam (Frederiksen and Renfro 1977), and Thailand. T. Hino in Pupipat (1975) claims it is absent from Japan.



Peronosclerospora sacchari distribution map (Prepared by Non-Regional Administrative Operations Office and Biological Assessment Support Staff, PPQ, APHIS, USDA).

Characters

IMPERFECT STAGE - Conidiophore structure and dimensions, and spore shape and size greatly vary under different culture conditions and at different developmental stages. Mycelium intercellular, haustoria bulbous. Conidiophores (Fig. 1) fugaceous, erect, one to four projecting through each stoma, hyaline, 125-190 X 18-25 µm, base bulbous, 1-2 septate, narrowing above, often with foot cell, middle part two to three times broader, tip dichotomously branched two or three times, each branch swollen in middle; ultimate branchlets bearing 2-4 sterigmata, sterigmata conical, pointed, slightly curved, length up to 12-30 µm (Mukerji and Holliday 1975). Base of main axis gradually tapers (Visarathanonth and Exconde 1976).

Conidia hyaline, ellipsoid, elongate ovoid to oblong; apex rounded, base slightly pedunculate or rounded, 25-55 X 15-25 (generally 36 X 18) µm, wall thin and smooth (Mukerji and

Holliday 1975); germ tube usually at apical end (Leu and Tan 1970a), hyaline, slender, nonseptate, width 3.8 μm (Sun 1970).

PERFECT STAGE - Oogonia from sugarcane reddish brown, irregularly elliptical; wall with two to three folds, thickness unequal, 49-58 X 55-73 μm (Sun 1970). Oospores yellow to yellowish brown, globular, diameter averages 50 μm, wall thickness 3.5-5.0 μm (Mukerji and Holliday 1975); germ tube hyaline, slender, nonseptate, width 3.8 μm (Sun 1970).

Characters for this pathogen and other downy mildew pathogens that infect corn in the United States are compared in Table 1.

(Fig. 1)

Mature Peronosclerospora sacchari conidiophores and conidia from A. sugarcane and B. corn (Courtesy M. R. Bonde, USDA photos).

Table 1. Comparison of Peronosclerospora sacchari with domestic downy mildew pathogens on corn (Shurtleff 1980). Natural hosts as listed by Kenneth (1981).

	Peronosclerospora		Sclerospora	Sclerophthora
	sacchari	sorghi	graminicola	macrospora
Conidiophores	Hyaline, length 160-170 µm, bloated, widening gradually, dichotomously branched 2-3 times, ephemeral	Hyaline, length 180-300 µm, bloated, often dichotomously branched 2-3 times, septate near base, ephemeral	Hyaline, length av. 268 µm, bloated, nonseptate, irregularly dichotomously branched, ephemeral	Hyaline, length av. 13.8 µm, simple, hyphoid, determinate
Asexual spores	Conidia hyaline, elliptical, oblong to conical, apex round, 25-41 X 15-23 µm	Conidia hyaline, oval to almost spherical, 15-26.9 X 15-28.9 µm	Sporangia hyaline, broadly elliptical, operculate, papillate, 14-23 X 11-17 µm	Sporangia hyaline, lemon-shaped, operculate, 60-100 X 30-65 µm
Germinate by	Germ tube	Germ tube	Zoospores	Many zoospores
Oospores	Yellow to yellow brown, globular to slightly angular, diameter 40-50 µm	Usually brown to subhyaline spherical, diameter 25-42.9 µm	Pale brown, spherical, usually smooth-walled, diameter 35 µm	Hyaline to pale yellow, mainly in vascular bundles, diameter 45-75 µm
Germinate by	Germ tube	Wide germ tube	Germ tube	Sporangium
Hosts	Miscanthus (Eulalia) Saccharum Sorghum Tripsacum Zea mays	Panicum trypheron Sorghum Zea mays	Echinacloa Panicum Pennisetum americanum Setaria Zea mays	Avena sativa Echinacloa Eleusine Eragrostis Hordeum vulgare Iseilema Miscanthus Oryza sativa Paspalum Pennisetum Saccharum Setaria Sorghum Triticum aestivum Zea mays, etc.

Characteristic Damage -- Sugarcane

Symptoms on plants grown from diseased sugarcane cuttings or setts appear on emerging shoots as a general mottled paleness of the young spindle, quickly followed by production of downy mildew on lower leaf surfaces. Stripes on young leaves are poorly defined but may involve large areas. Shoots fail to fully develop, becoming thin and stunted with leaves that are narrow, discolored, and upright. Shoots sometimes die early (Hughes and Robinson 1961).

Healthy sugarcane infected after planting exhibits symptoms 5-6 weeks or several months later depending on the cultivar, state of growth, and weather conditions. Any stalk, side bud, or late tiller can be infected. A slight pale mottling appears at the base of the oldest spindle leaf as it elongates and unrolls. As this leaf expands, pale green stripes develop at the base, extending 5-10 cm toward the tip and lengthening a little as the leaf reaches full size. Successive new leaves exhibit longer and longer stripes reaching toward the tip (Fig. 2). Stripes often fuse at the leaf base but remain separate toward the tip. Stripes never initially develop on mature leaves (Hughes and Robinson 1961). Infected at an older stage, sugarcane shows a few infected stalks but no systemic infection (Holliday 1980).

Stripes parallel leaf venation (sometimes confined to one-half of the blade width), number up to 40, are usually continuous, and measure 1-3 mm wide (up to 10 mm on susceptible cultivars). Stripes also appear on the midrib but not on the sheaths. In winter, expression is suppressed to very narrow stripes, with new leaves often showing a few short, inconspicuous stripes near the leaf base. With warmer conditions and active host growth, the characteristic stripes appear (Hughes and Robinson 1961).

With age, the stripe color changes from greenish yellow to yellow to a mottled reddish brown, and finally to a uniform dark red. Under favorable conditions for the fungus, stripes may fuse to form large, irregular, yellow or mottled red areas at the leaf tip. Reddening may be due to invasion by common saprophytic fungi (Hughes and Robinson 1961).

Fine, white downy mildew (Fig. 3) may appear before the leaf completely unrolls from the spindle or before the stripes are well defined. Down is restricted to streaked leaves in the blade area, more heavily on discolored than on green areas (Hughes and Robinson 1961).

Stalks are stunted, less so in those infected after planting than those from diseased setts. In late autumn or winter, some stalks elongate (Fig. 4) to twice the height of the usual

stalks. These thin, light, brittle, watery "jump-up canes" (Hughes and Robinson 1961), have more internodes (Holliday 1980). The few, short, narrow leaves fail to unfold, cling at the tips, wither, twist, and shred down the blade. Although these canes may bend or lodge, their tops (also abnormal) tower above the usual cane height. They usually die by the end of winter. Jump-up canes (when present), leaf twisting, and shredding are associated with the production of the brown

(Fig. 2)

Sugarcane downy mildew streaks on sugarcane leaves. Healthy leaf on far left (From Leece 1941).

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3. Sugarcane downy mildew on sugarcane leaf, undersurface.
4. Elongated sugarcane stalks or "jump-up" canes and sparse leaf development (From Leece 1941).

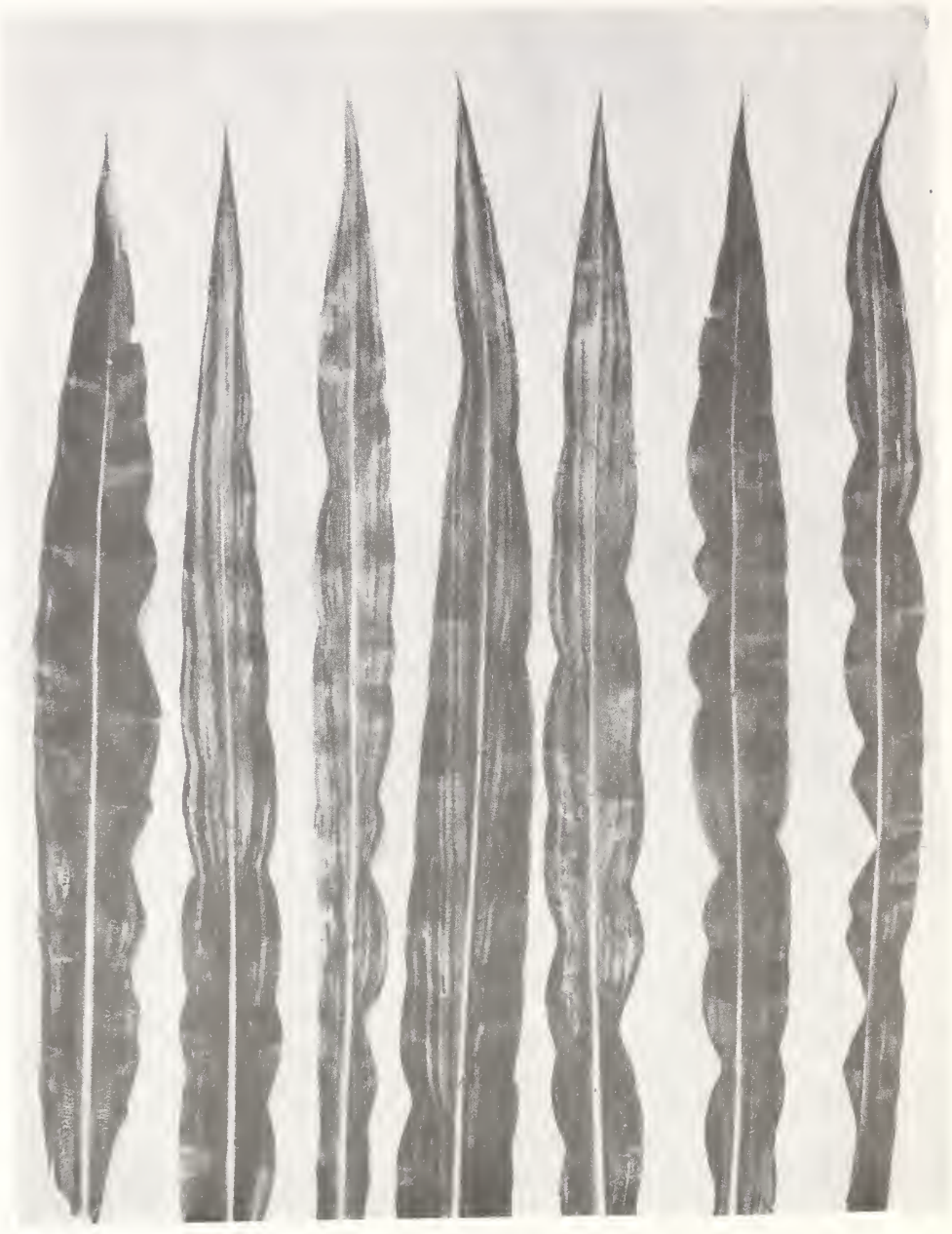
oospores lying between the leaf veins. Infected stalks that remain normal height are spindly with discolored tops and narrow, erect leaves (Hughes and Robinson 1961).

Corn

Systemic symptoms on corn appear as pale yellow to white stripes at the base of the third to sixth oldest leaves. Several stripes may form in each leaf and extend to the leaf tip (Fig. 5). With age, stripes become more yellow, new leaves more chlorotic, and leaf sheaths exhibit a streaked mosaic pattern. Leaves do not shred. Streaked areas may become necrotic due to attack by other pathogens. In late-infected or mildly infected plants, stripes may disappear as plants mature. Soon after systemic symptoms appear, white, downy or powdery masses appear in the chlorotic areas on both leaf surfaces, leaf sheaths, and husks. The number of symptomless leaves may reflect the age of the plant when it was infected, perhaps modified by some environmental factors affecting fungal development in the plant (Sun 1970).

Older leaves or leaves of resistant cultivars may show narrow, discontinuous stripes (Sun 1970). One-month-old corn plants are highly resistant, producing only local lesions with little or no sporulation (Holliday 1980, Mukerji and Holliday 1975).

(Fig. 5)



Sugarcane downy mildew streaks on corn leaves (From Leece 1941).

Depending on disease severity, corn may also be stunted, proliferate and tiller profusely, or sometimes die. Flowering is delayed with a prolonged difference between male and female flowering dates. Tassels are often imperfect. Ears are small, numerous (up to 12 per stalk), poorly filled, and sometimes at at the tops of the plants. Ear shanks are elongated, sometimes exceeding ear length (Chang 1970, Sun 1970).

Detection Notes

Movement of infected plant parts of the hosts of Peronosclerospora sacchari could introduce it into new areas. Because oospores of other downy mildew pathogens survive unfavorable conditions better than conidia or mycelia, long-distance dissemination of its oospores as a contaminant of various materials may be possible (Williams 1984). To prevent its introduction into the United States, Title 7 of the Code of Federal Regulations regulates the entry of corn, sugarcane, sorghum, and other grass relatives under Parts 319.15, 319.24, 319.37, and 319.41.

In sugarcane and corn, look for striped leaves with a white downy mildew that is either soft and velvety or fine and powdery on leaves (Hughes and Robinson 1961). Also look for

In sugarcane,

1. Stunted plants showing narrow, discolored, upright leaves and thin stalks. Very young plants exhibit a pale mottling of the young spindle and may be dead.

2. Stunted, spindly stools with upright, discolored leaves.

3. Leaves that, instead of showing leaf stripes, exhibit large irregular yellow or mottled red areas in advanced stages of the disease (Alfieri 1979).

4. In late fall or winter, some canes grow much taller and narrower than normal. Their stalks are brittle, leaves narrow, and tops discolored. The shredded leaves reveal the brown dusty oospores lying in the veins (Hughes and Robinson 1961).

In corn,

1. Young plants that are stunted and dead.

2. Older, stunted plants with heavy tillering, sterile tassels and ears, and no leaf shredding.

Submit specimens for identification by packing diseased material in double containers (one container inside another with screw lids).

Biology and Etiology

Oospores develop abundantly during late autumn or winter (Hughes and Robinson 1961) between leaf veins of sugarcane. Their role in the field is unknown, although infection of sugarcane has been reported in the greenhouse (Bonde 1982). Generally, the thick-walled, long-lived, resting, sexual

oospores of other graminaceous downy mildew pathogens carry them through long, unfavorable, host-free periods into the new crop season.

Infection can also begin from infected seed corn. The mycelium is seedborne in corn (Chang 1970, Singh et al. 1968).

The common primary inoculum, however, is the mycelium in infected perennial hosts, such as sugarcane (Sun 1970). In such hosts, this mycelium survives throughout the year and initiates infection in a new crop. During the growing season when conditions are favorable, the mycelium sends out conidiophores, which bear the asexual conidia, through host stomata. Sporulation (also germination and infection) on corn in the field in Taiwan occurred with mean minimum nights of 12-28° C (Bonde 1982). No conidia are produced at or below 13° C, or at or above 31° C (Sun 1970). Sporulation was profuse on corn from 15 to 23° C (Bonde and Melching 1979), or between 22 to 26° C (Leu 1973). Specific humidities are also required for sporulation. Relative humidities of 86 percent or more at night or a free film of moisture (Bonde 1982) is needed. A maximum number of conidia are produced between 22 and 25° C at 95 percent relative humidity.

The conidiophores discharge conidia at night (Sun 1970), mostly between 1:00 and 4:30 a.m. (Bonde 1982). Water splash or air currents disperse conidia to host tissue. Conidia remain viable for only a few hours even under optimum conditions (Hughes and Robinson 1961). Viability lasts for 3 hours at 100 percent relative humidity at 10° C, dropping to 1 hour at or below 95 percent relative humidity at 25° C (Sun 1970). Conidia are highly sensitive to desiccation, such as caused by sunlight, low humidity, or high winds. The short period of viability restricts the range of natural infection to a radius of 0.4 km (Hughes and Robinson 1961).

In vitro, conidia germinate optimally between 15 and 32° C. Systemic infection occurred at the lowest and highest temperatures tested, 8 and 32° C. No germination occurred at 6° C after 5 hours of incubation (Bonde and Melching 1979).

Once conidia land on suitable host tissue (expanding buds and young leaf tissues in sugarcane and leaves in young corn) with suitable moisture present, they germinate and produce germ tubes, which penetrate corn leaves through the stomata after 2 hours at 25° C (Holliday 1980, Mukerji and Holliday 1975). Tiny round local lesions covered with ectophytic mycelium develop at the infection sites. Internally, the mycelium spreads intercellularly and invades host cells with its knob-like haustoria. After mycelium invades the growing point of

its host, the first streaks appear on new, young leaves. These symptoms are soon followed by production of conidia, within 2 weeks after infection for corn. These conidia serve as the secondary inoculum for more infections (Sun 1970). New conidiophores release more conidia nightly.

Maximum disease spread occurs during summer when frequent rains and warm temperatures stimulate the production of a tremendous inoculum load and rapid plant growth results in much susceptible host tissue (Hughes and Robinson 1961). Major factors affecting disease development are temperature, moisture, distance from the inoculum source, and age of the plant. Night temperatures of 20-25° C and free moisture on host tissue result in production of tremendous numbers of conidia every night (Sun 1970). One infected sugarcane leaf can release more than 20,000 per sq cm in one night (Leu and Tan 1970b). Susceptible hosts within 0.4 km of the source of the inoculum can be affected. Only corn less than 1 month old is susceptible, but corn planted at various dates provides a continuous supply of susceptible hosts (Sun 1970).

Several of the suscepts mentioned by Bonde and Peterson (1983) are common perennial grasses in the United States that might allow this pathogen to overwinter and serve as an inoculum source the following spring (Bonde 1980). Systemic infection was induced during the lowest tested dew period of 4 hours at 12° and 18-32° C. These conditions are common during the growing season in the U.S. corn belt (Bonde and Melching 1979).

Cultural Controls

Planting resistant cultivars appears to be the most effective control method. The following sanitation practices helpes to prevent the introduction of inoculum and suppress its buildup.

1. Planting disease-free sugarcane cuttings or setts. If diseased or suspect setts must be used, the fungus was reported controlled by soaking in water at 45° C for 1 hour, drying at room temperature for 24 hours, and soaking again at 52° C for 1 hour or 55° C for 0.5 hour (Wang and Wang 1958).

2. Destruction of dead leaves of infected sugarcane to destroy the oospores. Roguing and destruction of infected stalks and susceptible hosts within 0.4 km of the affected site, followed by continuous destruction of infected secondary stalks and late suckers (Hughes and Robinson 1961).

3. Removal and burning of infected corn ears because burial or piling to the side of the field ensures inoculum for primary infection. If the seed must be planted, drying the seed below 20 percent moisture destroys the mycelium (Chang 1970).

Other suggested practices might include avoidance of staggered planting dates and protection of young corn plants.

Epiphytotics in Taiwan were brought under control by elimination of infected plants islandwide, prohibition of planting of susceptible cultivars of corn and sugarcane in severely affected areas, and substitution of tolerant for susceptible sugarcane cultivars (Chang 1970).

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